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Approaches in Green Computing

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***Abstract*— In a 2008 article San Murugesan defined green computing as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems — such as monitors, printers, storage devices, and networking and communications systems — efficiently and effectively with minimal or no impact on the environment."Murugesan lays out four paths along which he believes the environmental effects of computing should be addressed:Green use, green disposal, green design, and green manufacturing. Green computing can also develop solutions that offer benefits by "aligning all IT processes and practices with the core principles of sustainability, which are to reduce, reuse, and recycle; and finding innovative ways to use IT in business processes to deliver sustainability benefits across the enterprise and beyond".**

I. INTRODUCTION

In 1992, the U.S. Environmental Protection Agency launched Energy Star, a voluntary labeling program that is designed to promote and recognize energy-efficiency in monitors, climate control equipment, and other technologies. This resulted in the widespread adoption of sleep mode among consumer electronics. Concurrently, the Swedish organization TCO Development launched the TCO Certification program to promote low magnetic and electrical emissions fromCRT-based computer displays; this program was later expanded to include criteria on energy consumption, ergonomics, and the use of hazardous materials in construction.

Modern IT systems rely appon a complicated mix of people, networks, and hardware; as such, a green computing initiative must cover all of this area as well. A solution may also need to address end user satisfaction, management, restructuring, regulatory compliance, and return on investment(ROI). There are also considerable fiscal motivation for companies to take control of their own power consumption;"of the power management tools available, one of the most powerful may still be simple, plain, common sense."

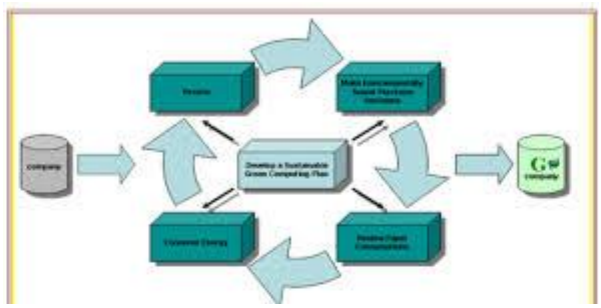

Figure 1: Green Computing Migration Framework

II. APPROACHES

A. *Product longevity*

Gartner maintains that the PC manufacturing process accounts for 70% of the natural resources used in the life cycle of a PC. More recently, Fujitsu released a Life Cycle Assessment (LCA) of a desktop that show that manufacturing and end of life accounts for the majority of this desktop's ecological footprint.Therefore, the biggest contribution to green computing usually is to prolong the equipment's lifetime.

B. *Data center design*

Energy efficient data center design should address all of the energy use aspects included in a data center: from the IT equipment to the HVAC equipment to the actual location, configuration and construction of the building.

The U.S. Department of Energy specifies five primary areas on which to focus energy efficient data center design best practices:

- Information technology (IT) systems
- Environmental conditions
- Air management
- Cooling systems
- Electrical systems

Additional energy efficient design opportunities specified by the U.S. Department of Energy include on-site electrical generation and recycling of waste heat.

Energy efficient data center design should help to better utilize a data center's space, and increase performance and efficiency.

C. Software and deployment optimization

- Algorithmic efficiency

The efficiency of algorithms has an impact on the amount of computer resources required for any given computing function and there are many efficiency trade-offs in writing programs. Algorithm changes, such as switching from a slow (e.g. linear) search algorithm to a fast (e.g. hashed or indexed) search algorithm can reduce resource usage for a given task from substantial to close to zero.

- Resource allocation

Algorithms can also be used to route data to data centers where electricity is less expensive. .Larger server centers are sometimes located where energy and land are inexpensive and readily available. Local availability of renewable energy, climate that allows outside air to be used for cooling, or locating them where the heat they produce may be used for other purposes could be factors in green siting decisions. Approaches to actually reduce the energy consumption of network devices by proper network/device management techniques are surveyed in.The authors grouped the approaches into 4 main strategies, namely (i) Adaptive Link Rate (ALR), (ii) Interface Proxying, (iii) Energy Aware Infrastructure, and (iv) Energy Aware Applications.

- Virtualizing

Computer virtualization refers to the abstraction of computer resources, such as the process of running two or more logical computer systems on one set of physical hardware. With virtualization, a system administrator could combine several physical systems into virtual machines on one single, powerful system, thereby unplugging the original hardware and reducing power and cooling consumption. Virtualization can assist in distributing work so that servers are either busy or put in a low-power sleep state.

Figure 2: Virtualization

- Terminal servers

Terminal servers have also been used in green computing. When using the system, users at a terminal connect to a central server; all of the actual computing is done on the server, but the end user experiences the operating system on the terminal. These can be combined with thin clients, which use up to 1/8 the amount of energy of a normal workstation, resulting in a decrease of energy costs and consumption. There has been an increase in using terminal services with thin clients to create virtual labs. Examples of terminal server software include Terminal Services for Windows and the Linux Terminal Server Project (LTSP) for the Linux operating system.

D. Power management

The Advanced Configuration and Power Interface (ACPI), an open industry standard, allows an operating system to directly control the power-saving aspects of its underlying hardware. This allows a system to automatically turn off components such as monitors and hard drives after set periods of inactivity. In addition, a system may hibernate, when most components (including the CPU and the system RAM) are turned off. ACPI is a successor to an earlier Intel-Microsoft standard called Advanced Power Management, which allows a computer's BIOS to control power management functions. Some programs allow the user to manually adjust the voltages supplied to the CPU, which reduces both the amount of heat produced and electricity consumed. This process is called undervolting. Some CPUs can automatically undervolt the processor, depending on the workload; this technology is called "SpeedStep" on Intel processors, "PowerNow!"/"Cool'n'Quiet" on AMD chips, LongHaul on VIA CPUs, and LongRun with Transmeta processors.

- Data center power

Data centers, which have been criticized for their extraordinarily high energy demand, are a primary focus for proponents of green computing. Data centers can potentially improve their energy and space efficiency through techniques such as storage consolidation and virtualization. The first step toward this aim will be training of data center administrators. The U.S. federal government has set a minimum 10% reduction target for data center energy usage by 2011.

- Operating system support

Microsoft Windows, has included limited PC power management features since Windows 95.These initially provided for stand-by (suspend-to-RAM) and a monitor low power state. This required major changes to the underlying operating system architecture and a new hardware driver model. However, power management was not one of those features. This is probably because the power management settings design relied upon a connected set of per-user and per-machine binary registry values, effectively leaving it up to each user to configure their own power management settings.There is a significant market in third-party PC power management software offering features beyond those present in the Windows operating system available. Most products offer Active Directory integration and per-user/per-machine settings with the more advanced offering multiple power plans, scheduled power plans, anti-insomnia features and enterprise power usage reporting.

- Power supply

Desktop computer power supplies (PSUs) are in general 70–75% efficient, dissipating the remaining energy as heat. A certification program called 80 Plus certifies PSUs that are at least 80% efficient; typically these models are drop-in replacements for older, less efficient PSUs of the same form factor.

- Storage

Figure 3: Green Computing Power Supply and Displays

Smaller form factor (e.g., 2.5 inch) hard disk drives often consume less power per gigabyte than physically larger drives.Unlike hard disk drives, solid-state drives store data in flash memory or DRAM. With no moving parts, power consumption may be reduced somewhat for low-capacity flash-based devices.The increase in online storage has increased power consumption. Reducing the power consumed by large storage arrays, while still providing the benefits of online storage, is a subject of ongoing research.

- Video card

A fast GPU may be the largest power consumer in a computer.Energy-efficient display options include:

- No video card - use a shared terminal, shared thin client, or desktop sharing software if display required.
- Use motherboard video output - typically low 3D performance and low power.
- Select a GPU based on low idle power, average wattage, or performance per watt.

- Display

CRT monitors typically use more power than LCD monitors. They also contain significant amounts of lead. LCD monitors typically use a cold-cathode fluorescent bulb to provide light for the display. Some newer displays use an array of light-emitting diodes (LEDs) in place of the fluorescent bulb, which reduces the amount of electricity used by the display. Fluorescent back-lights also contain mercury, whereas LED back-lights do not.

E. Materials recycling

Recycling computing equipment can keep harmful materials such as lead, mercury, and hexavalent chromium out of landfills, and can also replace equipment that otherwise would need to be manufactured, saving further energy and emissions. Computing supplies, such as printer cartridges, paper, and batteries may be recycled as well. A drawback to many of these schemes is that computers gathered through recycling drives are often shipped to developing countries where environmental standards are less strict than in North America and Europe. The Silicon Valley Toxics Coalition estimates that 80% of the post-consumer e-waste collected for recycling is shipped abroad to countries such as China and Pakistan.The recycling of old computers raises an important privacy issue. The old storage devices still hold private information, such as emails, passwords, and credit card numbers, which can be recovered simply by someone's using software available freely on the Internet. Deletion of a file does not actually remove the file from the hard drive. Before recycling a computer, users should remove the hard drive, or hard drives if there is more than one, and physically destroy it or store it somewhere safe. There are some authorized hardware recycling companies to whom the computer may be given for recycling, and they typically sign a non-disclosure agreement.

F. Telecommuting

Teleconferencing and telepresence technologies are often implemented in green computing initiatives. The advantages are many; increased worker satisfaction, reduction of greenhouse gas emissions related to travel, and increased profit margins as a result of lower overhead costs for office space, heat, lighting, etc

G. Telecommunication network devices energy indices

The information and communication technologies (ICTs) energy consumption, in the USA and worldwide, has been estimated respectively at 9.4% and 5.3% of the total

Figure 4: Telecommunicating

electricity produced.The energy consumption of ICTs is today significant even when compared with other industries.

H. Supercomputers

Today a new supercomputer, L-CSC from the GSI Helmholtz Center, Made in Germany emerged as the most energy-efficient (or greenest) supercomputer in the world. The L-CSC cluster was the first and only supercomputer on the list to surpass 5 gigaflops/watt (billions of operations per second per watt). L-CSC is a heterogeneous supercomputer that is powered by Dual Intel Xeon E5-260 and GPU accelerators, namely AMD FirePro™ S9150 GPUs. It marks the first time that a supercomputer using AMD GPUs has held the top spot. Each server has a memory of 256 gigabytes. Connected, the server via an Infiniband FDR network.

III CONCLUSION

Green Computing is not only a new trend; it is a technology of itself. The move to become more environmentally friendly is more than just a means to a better corporate image; it is also a means to cost reduction in an ever inflating IT budget. New and improved ways of using this technology seem to appear everyday. The important key to remember is that while all of these technologies are beneficial in some way, the most beneficial to existing corporations are those that directly affect their processes and IT infrastructures. Reducing the number of servers using virtualization is a great way to consolidate but in order to get the maximum benefit the corporation must reorganize its datacenter infrastructure and in addition, rethink processes and procedures that utilize these resources from the user's standpoint.

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